

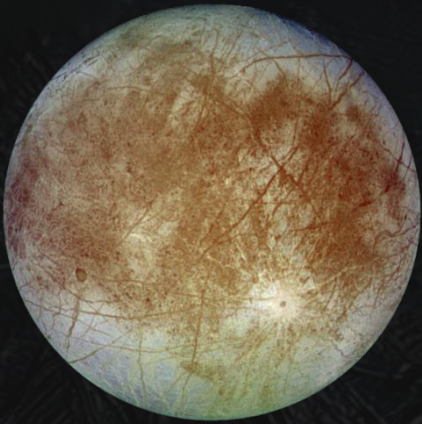
Extensional terrain formation in icy satellites:

Implications for ocean-surface interaction

Sam Howell (3220)
Robert Pappalardo (3204)

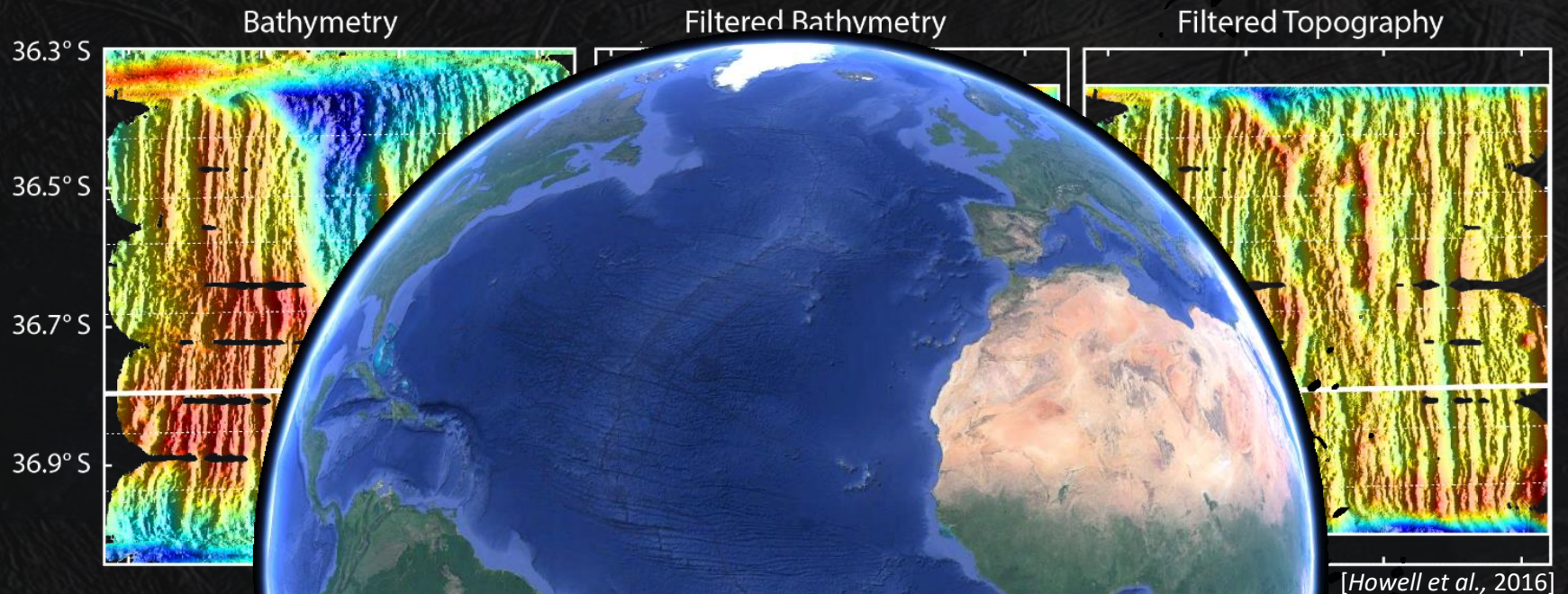
Jet Propulsion Laboratory, California Institute of Technology.

Postdoc Award Ceremony,
September 22, 2017
NASA Jet Propulsion Lab



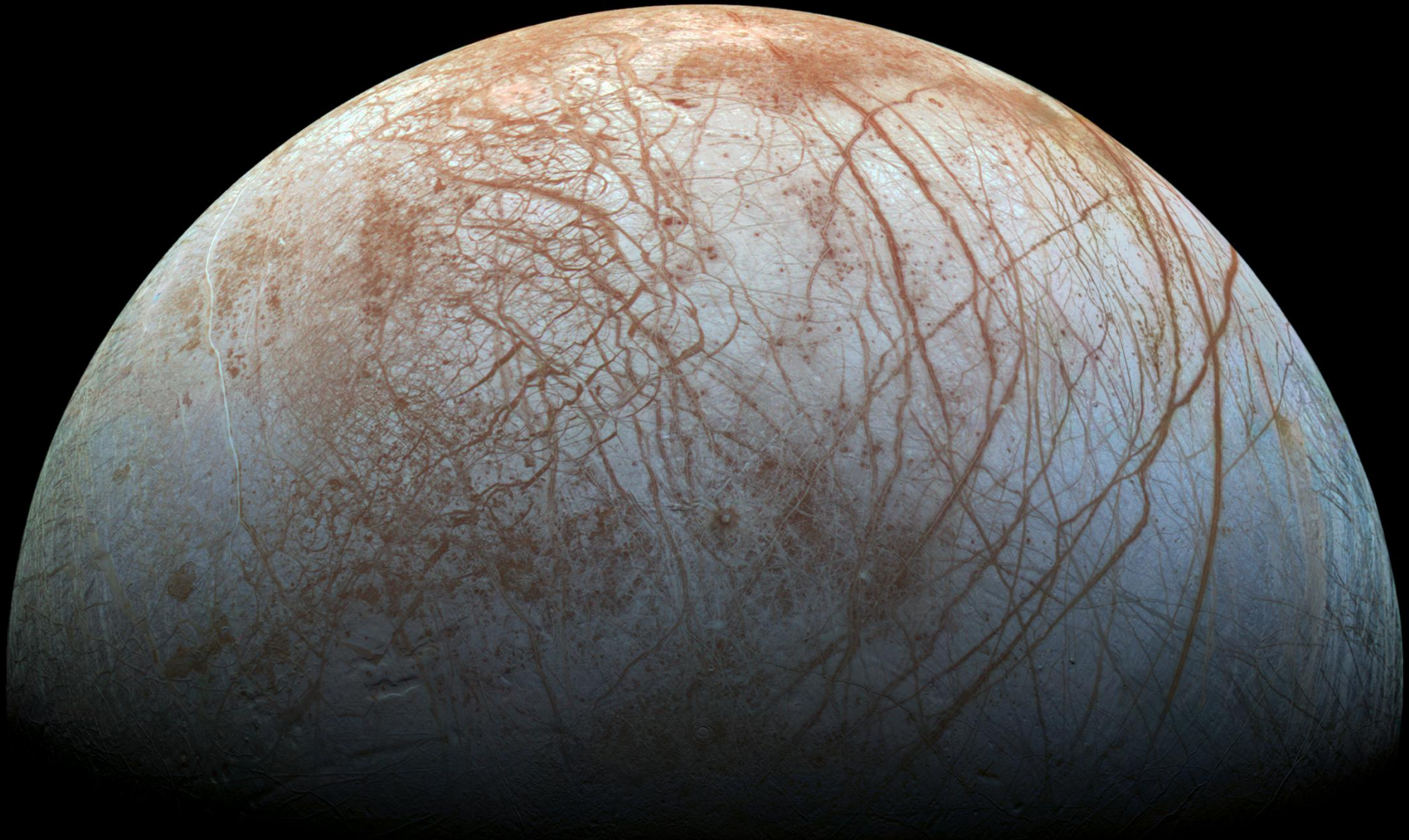
Jet Propulsion Laboratory
California Institute of Technology

Motivation for tectonic modeling



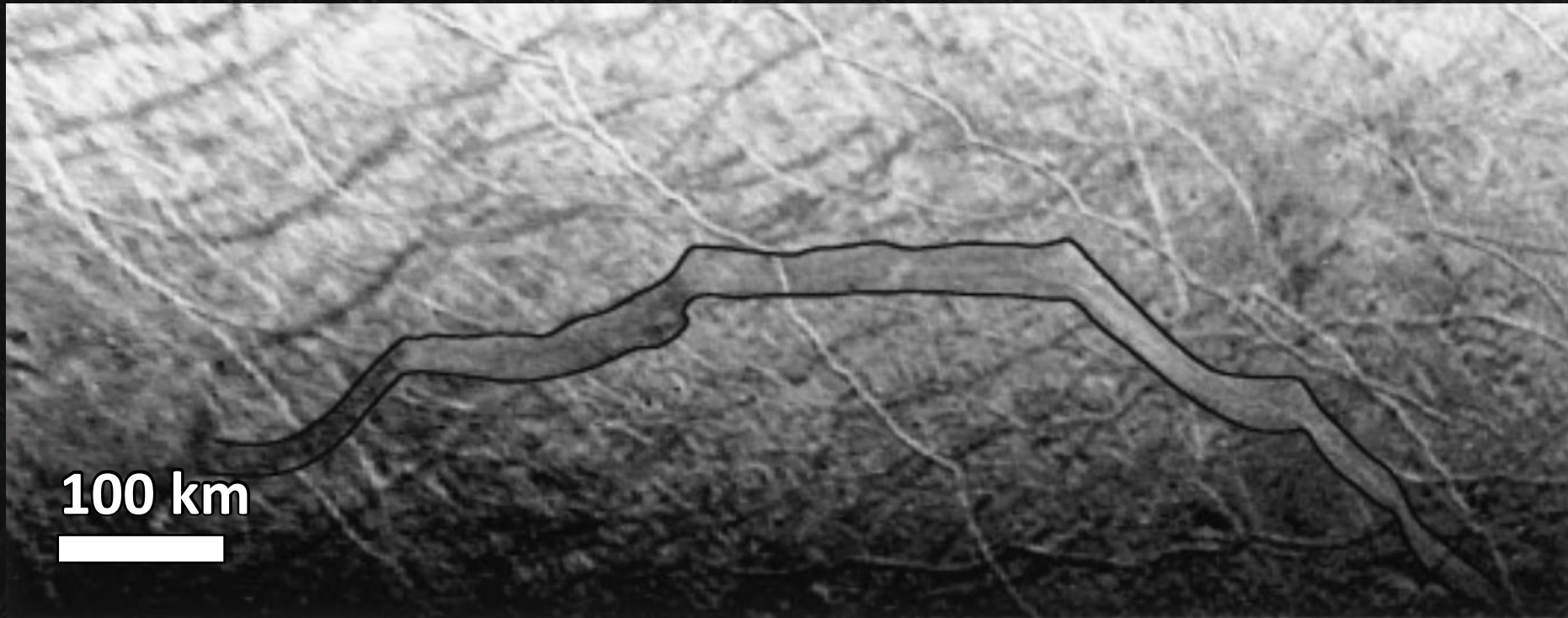
- The study of
- The morphology of faults grant us an insight into critical
- The spacing of faults
- The length of faults can
- The width and depth of the Mid-Atlantic Ridge illuminate its mechanical properties
- Heat flux through the lithosphere and

And then I saw Europa...



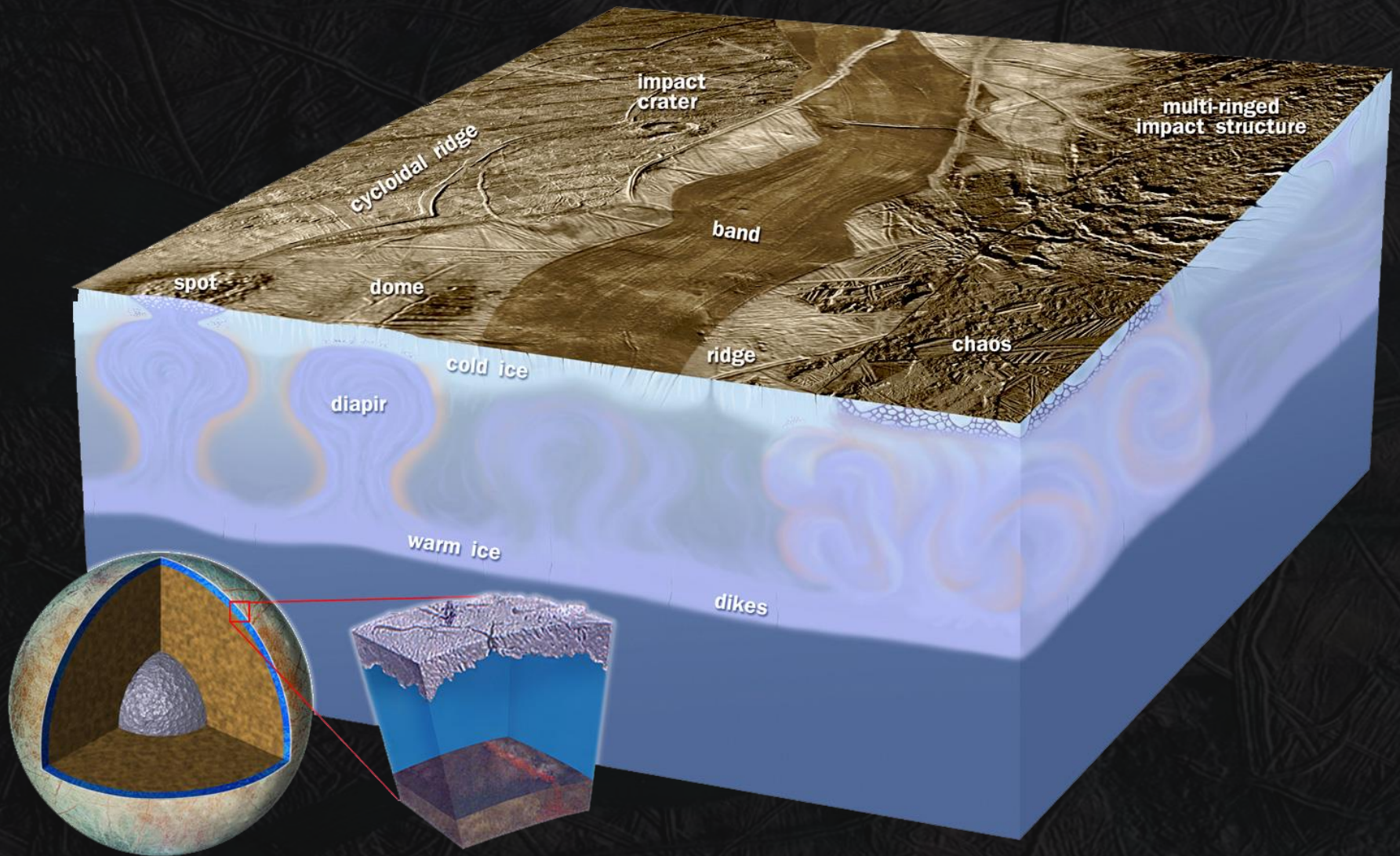
Bands and Extension

Reconstruction of Thynia Linea

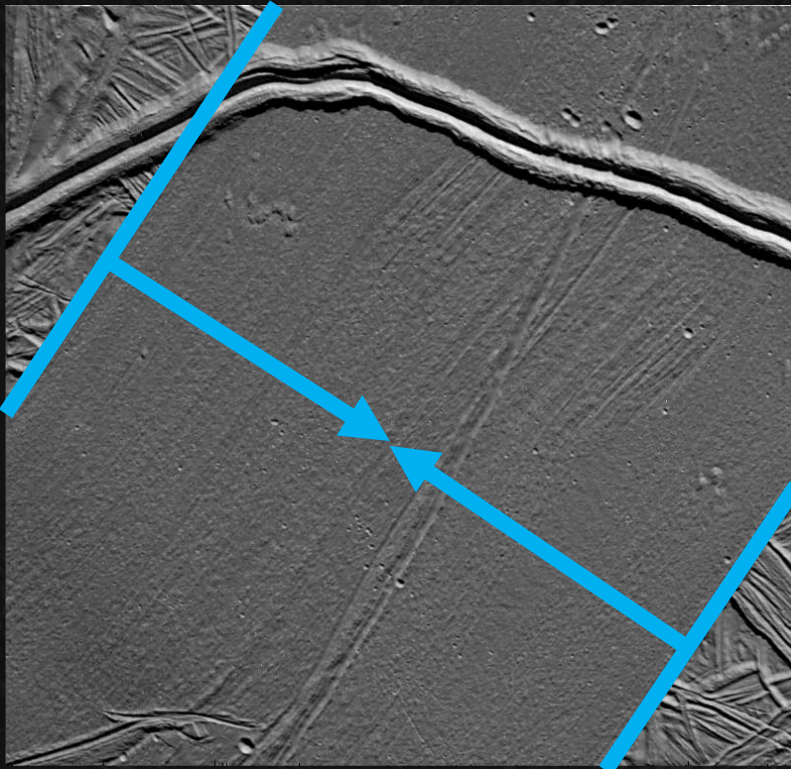


[Pappalardo and Sullivan., 1996]

The Ice Shell

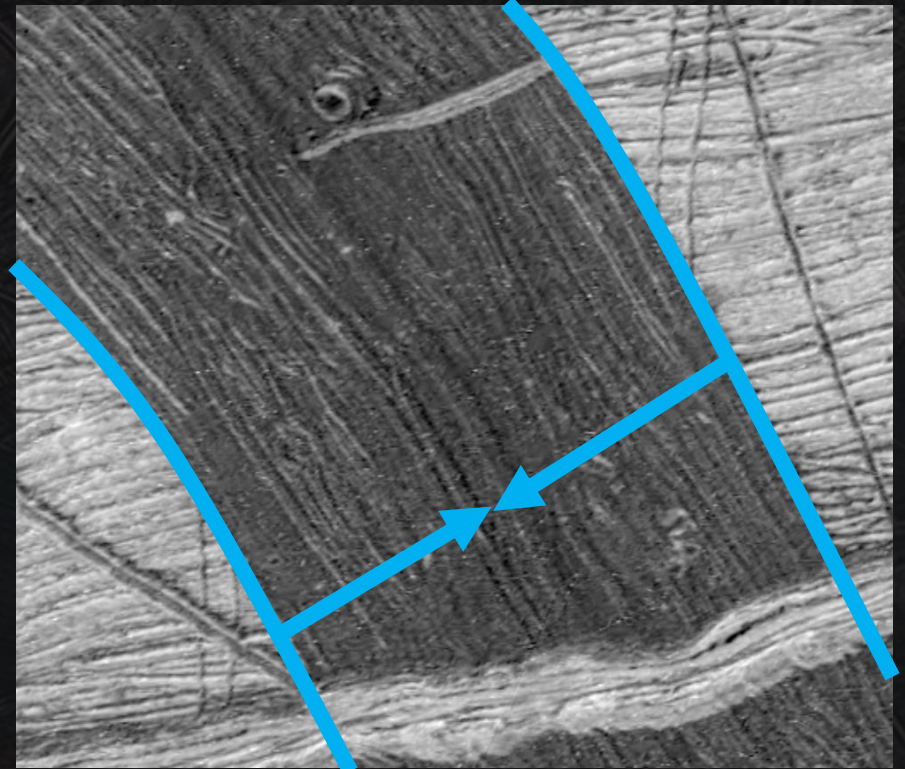


Band Types



10 km

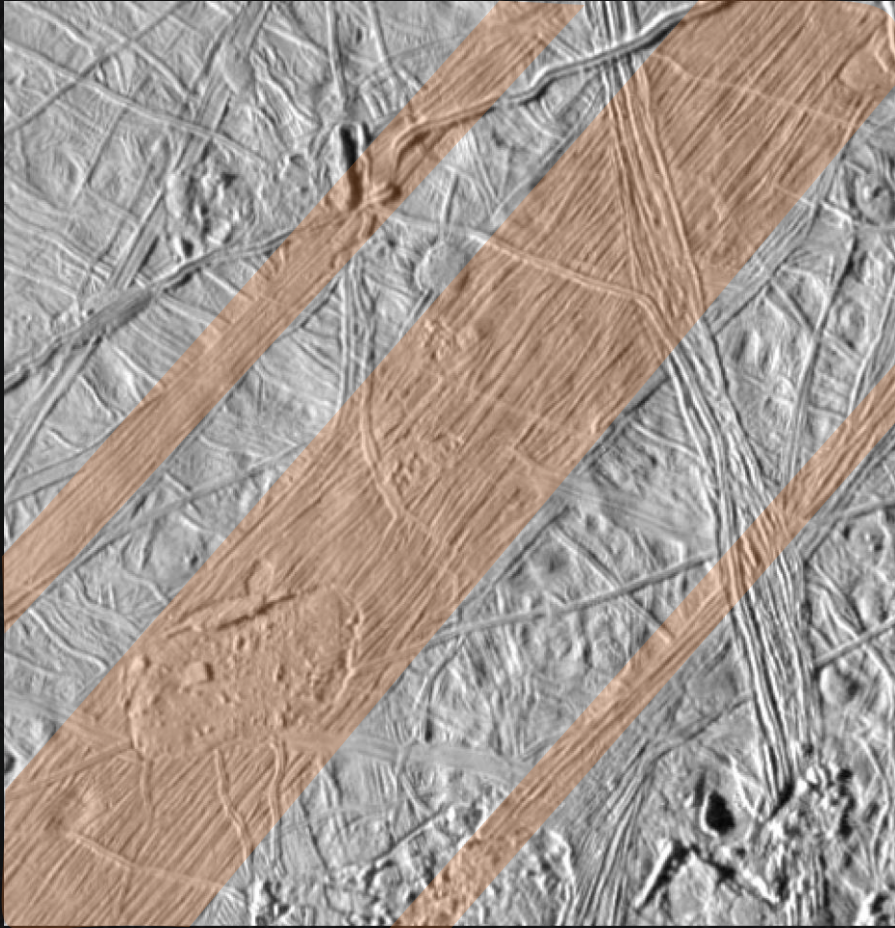
Smooth band
Thynia Linea (Europa)



10 km

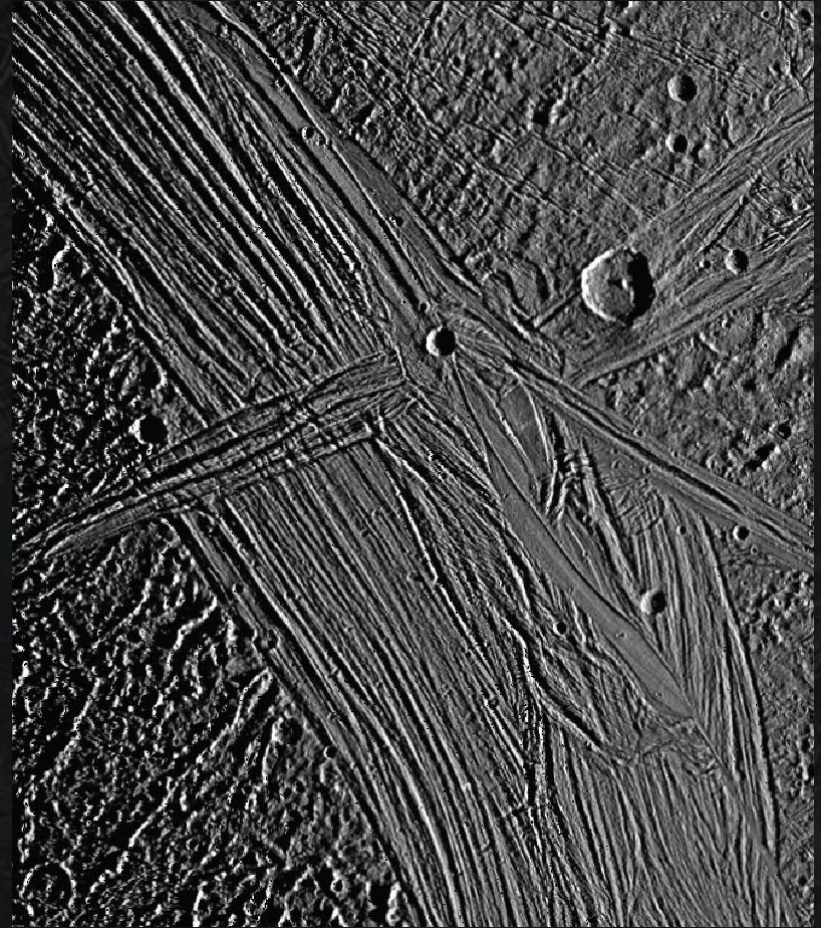
Lineated band
Yelland Linea (Europa)

Band Types



10 km

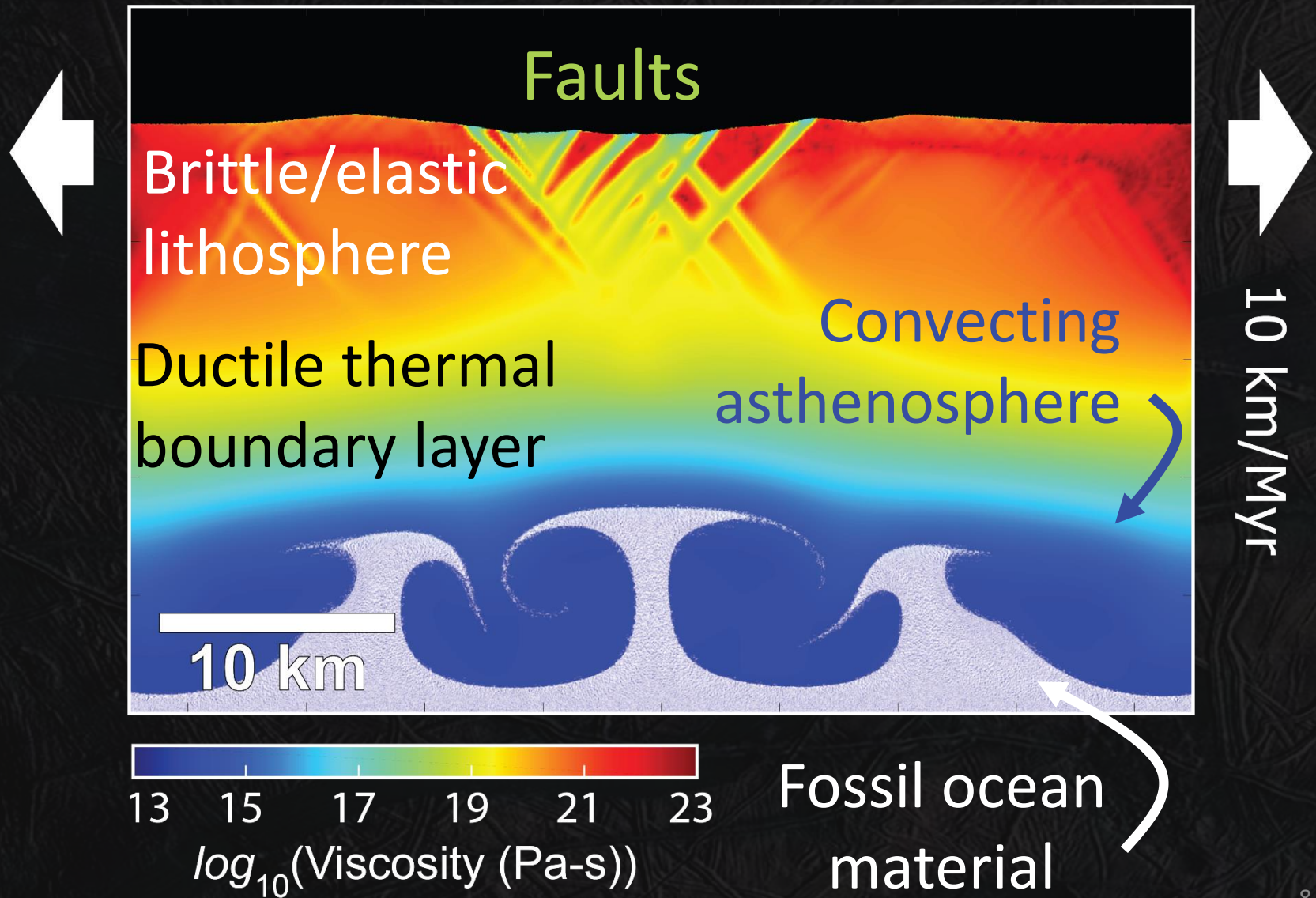
Ridged band
Unnamed (Europa)



10 km

Groove lane
Tiamat sulcus (Ganymede)

Numerical modeling



Governing and constitutive equations

(I'm sorry)

Conservation of Mass:

$$\nabla v = 0$$

Conservation of Momentum:

$$\eta \nabla^2 v + \rho g = \nabla p$$

viscous forces body forces sources and sinks

Conservation of Heat:

$$\rho C_p \frac{DT}{Dt} - \nabla q = H$$

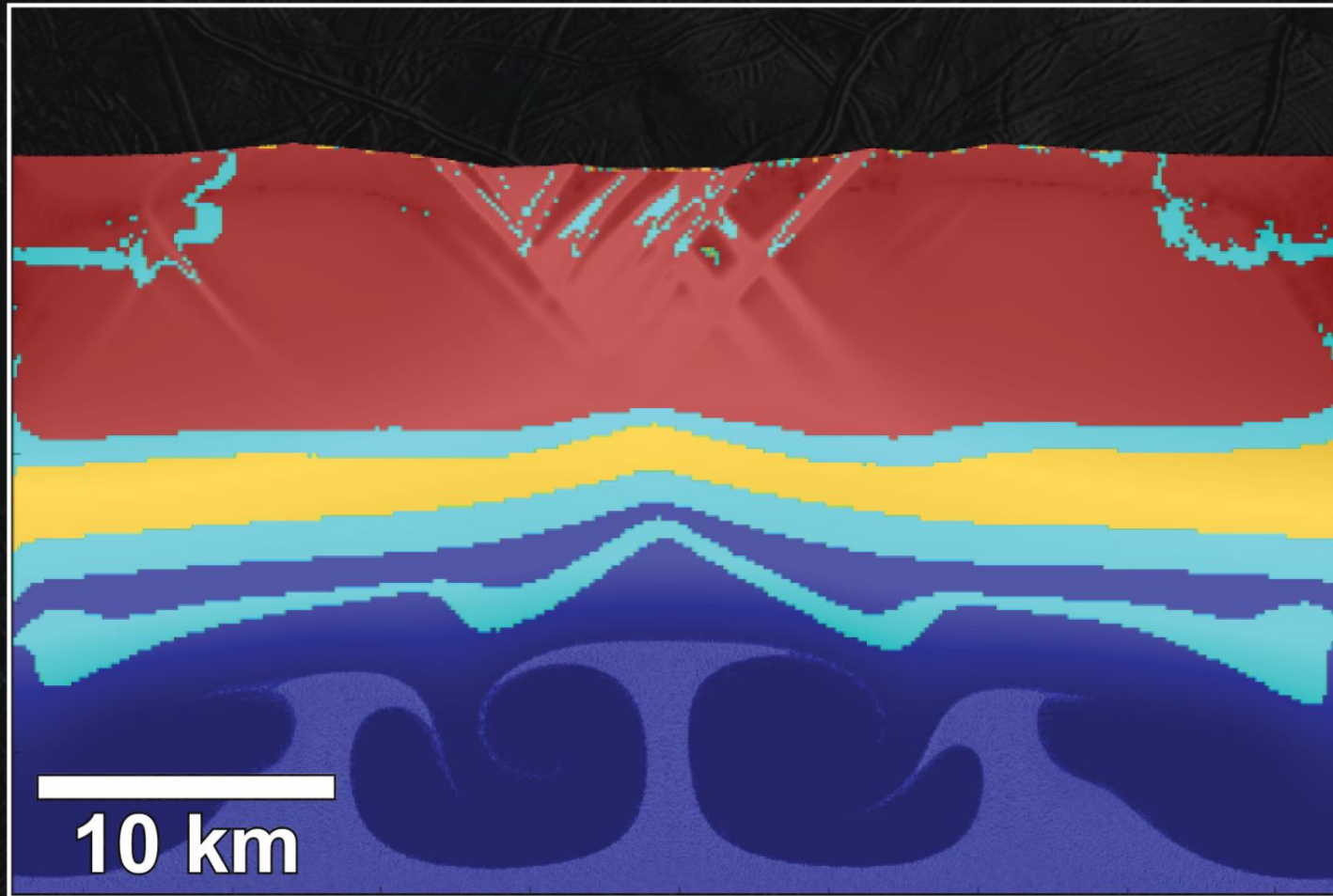
convective heat transport conduction (contains temperature and conductivity gradients) heat generation

Maxwell solid

$$\dot{\epsilon} = \frac{1}{2\eta_v} \sigma' + \frac{1}{2G} \frac{\partial \sigma'}{\partial t}$$

how fast it deforms Viscous how hard you deform it Elastic

Deformation Mechanisms

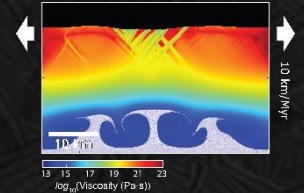


Dislocation creep

Diffusion creep

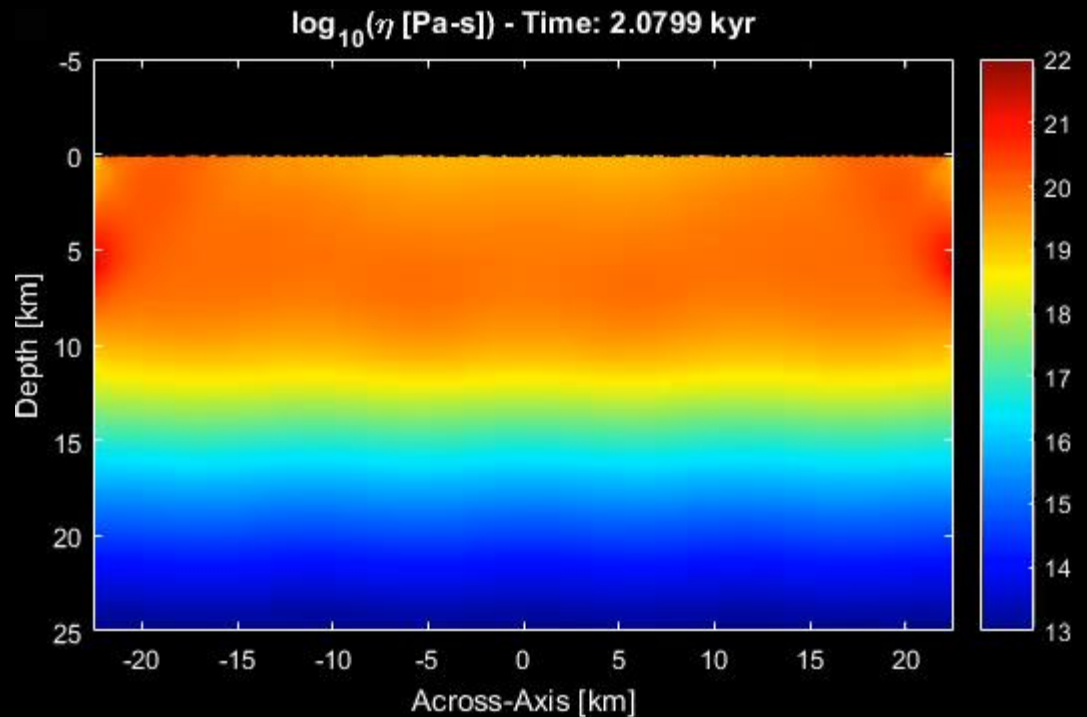
GBS

Basal slip



25 km shell
 $\eta(T_{\text{melt}}) = 10^{13} \text{ Pa s}$
no fault healing

Small faults quickly
transition to plastic yielding
(conveyor belt)

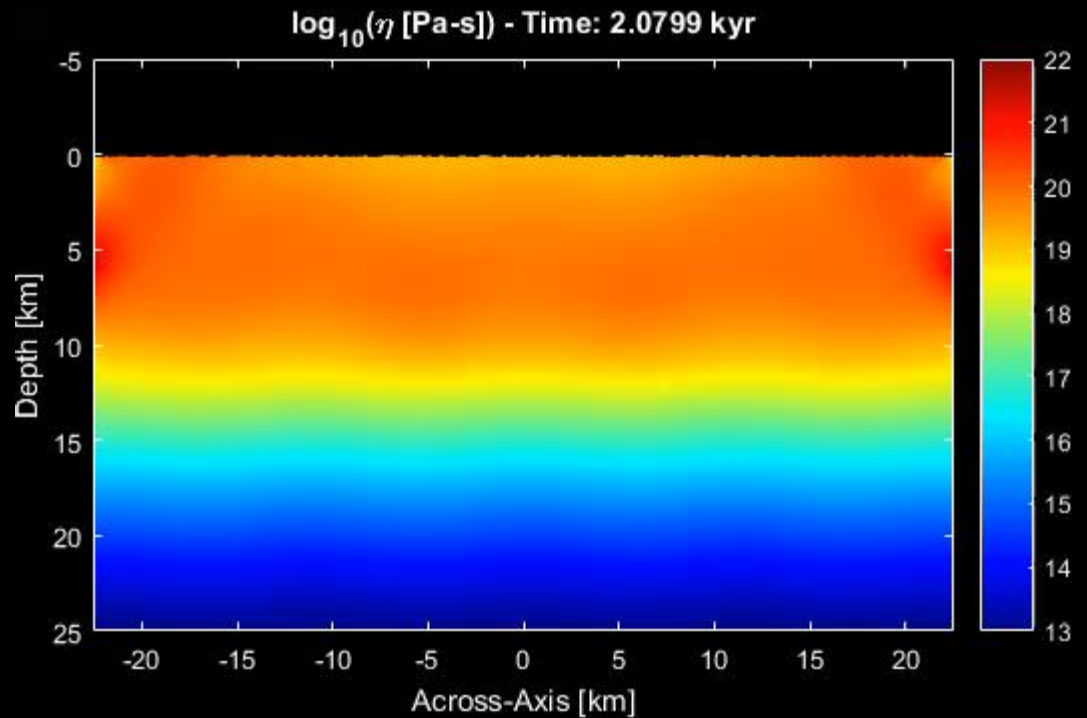


Fossil ocean can reach
surface after $\sim 1 \text{ Myr}$ (20 km
total opening)

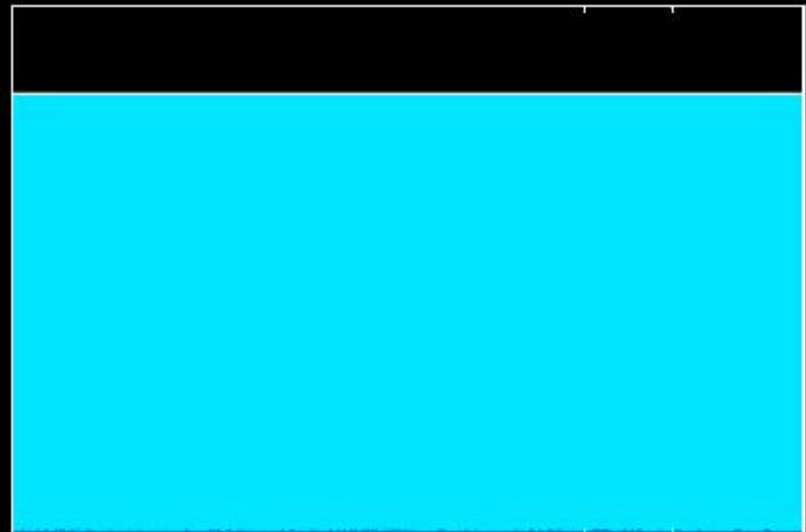


25 km shell
 $\eta(T_{\text{melt}}) = 10^{13} \text{ Pa s}$
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Small faults quickly
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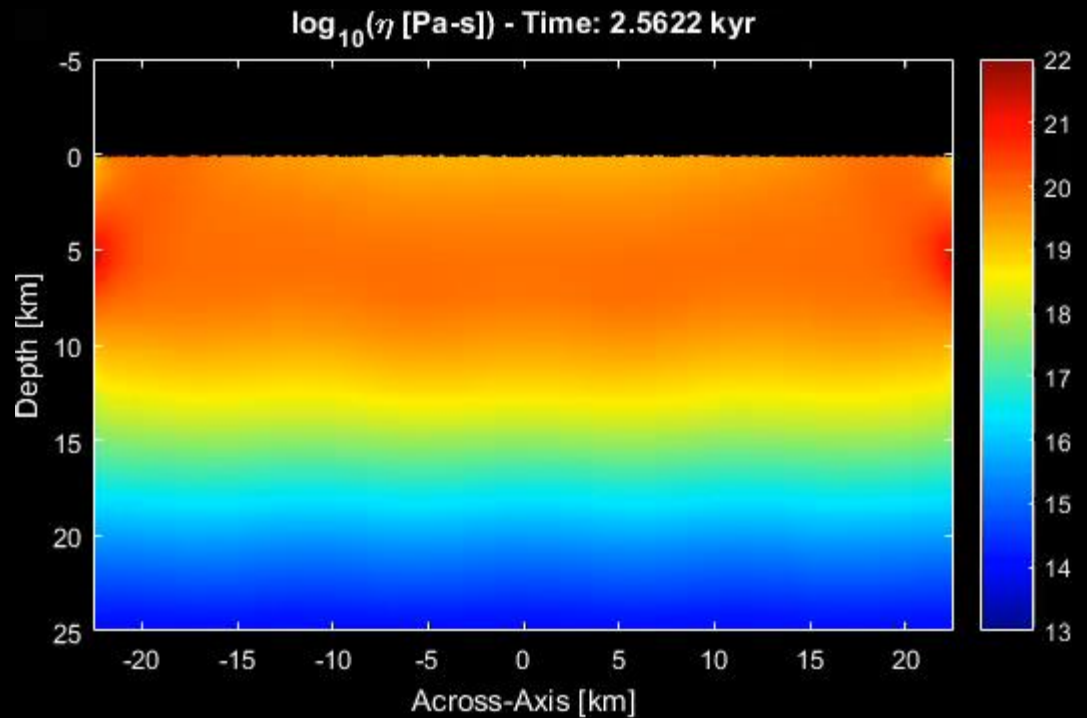


Fossil ocean can reach
surface after $\sim 1 \text{ Myr}$ (20 km
total opening)

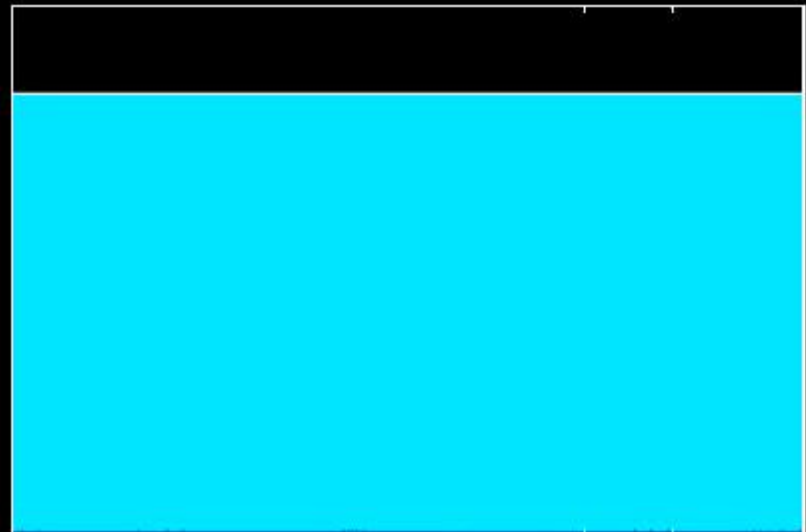


25 km shell
 $\eta(T_{\text{melt}}) = 10^{14} \text{ Pa s}$
no fault healing

Small faults transition to
plastic yielding (conveyor
belt) a little more slowly



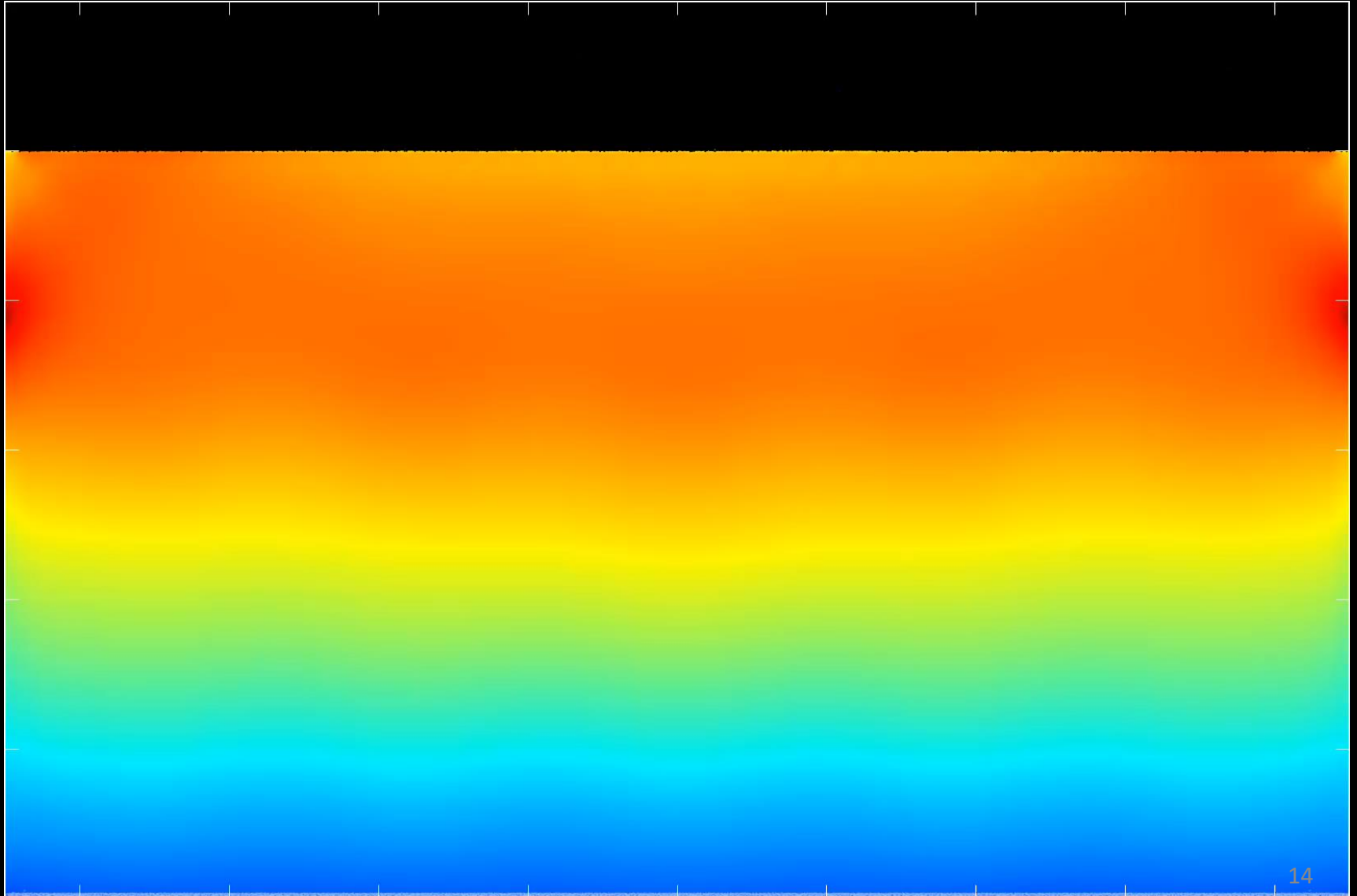
Fossil ocean doesn't quite
reach surface after $\sim 1 \text{ Myr}$
(20 km total opening)



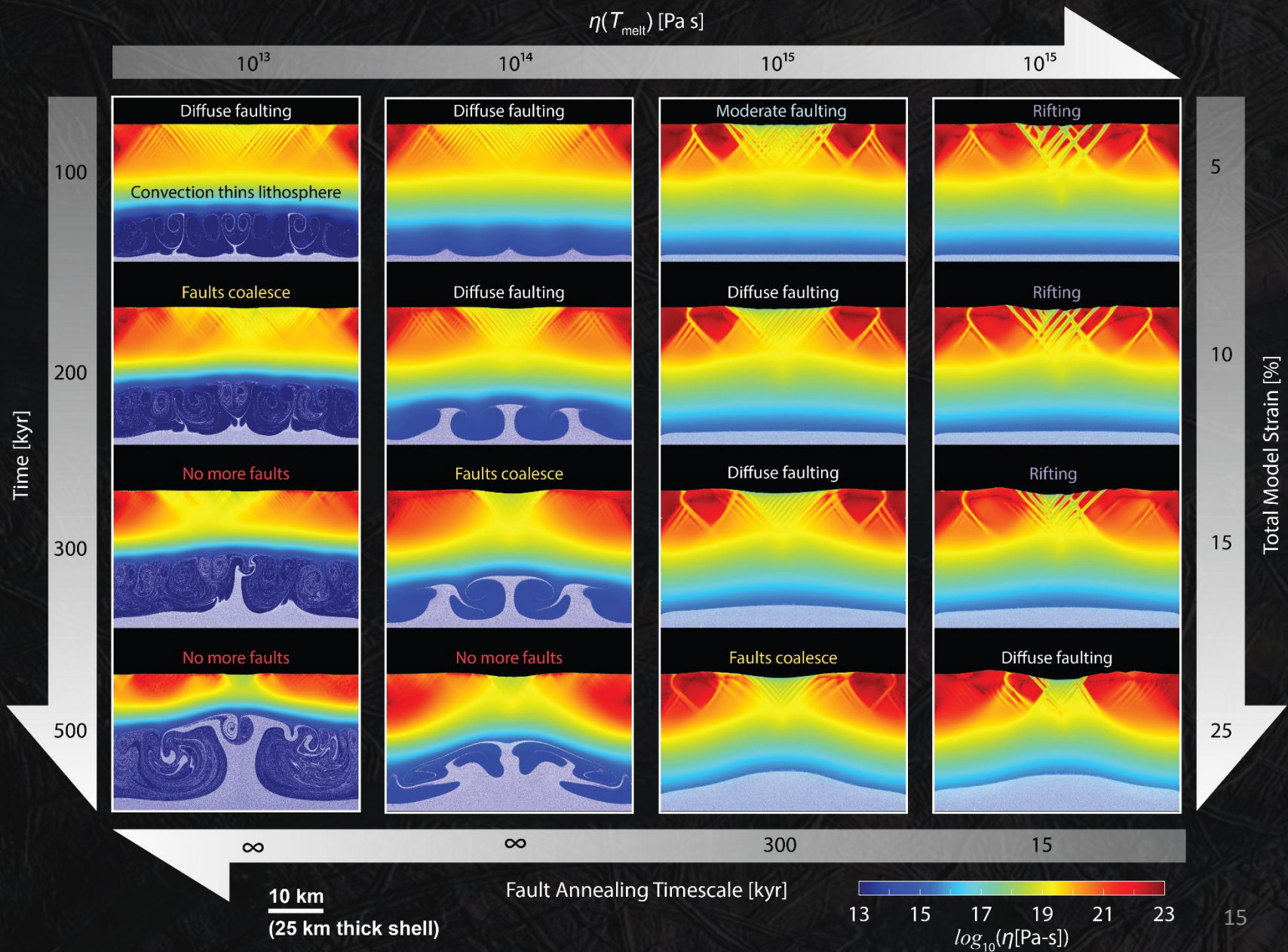
25 km shell
 $\eta(T_{\text{melt}}) = 10^{15} \text{ Pa s}$
15 ky annealing timescale

Rifting transitions to plastic
yielding only after
 $\sim 750 \text{ kyr}$

Fossil ocean nowhere near
surface after $\sim 1 \text{ Myr}$ (20 km
total opening)

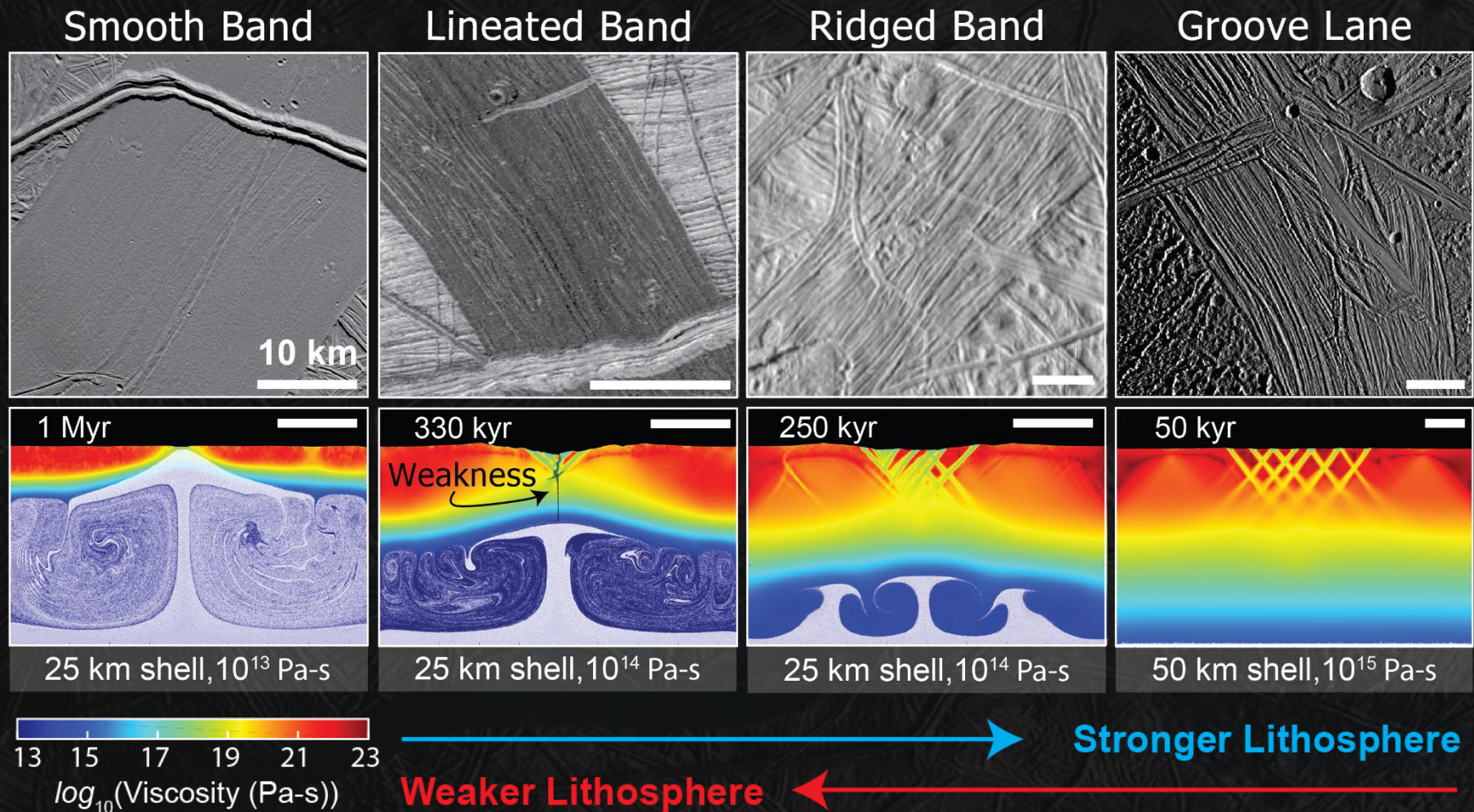


Summary of Example Models



Conclusion: A spectrum of extensional terrains

- Bands share a common formation spectrum
- Band type is an indicator of relative lithosphere strength



Questions?

- Bands share a common formation spectrum
- Band type is an indicator of relative lithosphere strength

